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INTERIM REPORT - UPPER OTTAWA STREET LANDFILL SITE STUDY, REFERENCE PAPER 19 : MULTILEVEL DEVICE FOR GROUND-WATER SAMPLING ...

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A MULTILEVEL DEVICE FOR GROUNDWATER SAMPLING AND WATER LEVEL MONITORING IN FRACTURED ROCK

A Preliminary Report

By:

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Submitted To:

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42 James Street South, Suite 33
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February 1, 1982

INTRODUCTION

The identification and delineation of zones of contaminated groundwater in fractured bedrock at waste disposal sites is a difficult task because of the complex nature of flow in the fracture networks. The rates of groundwater flow and the concentrations of contaminants can be greatly different from one fracture to another. In boreholes at sites where contaminated groundwater is expected to occur, contaminants may be present in fractures that intersect only a small segment of the total length of the borehole. Because of the complexities and uncertainties, it is often appropriate in monitoring of groundwater quality in fractured rock to acquire groundwater samples from numerous depth intervals at each monitoring site. This can be accomplished by drilling boreholes of many different depths at each site for installation of a separate piezometer or observation well in each hole or by the installation of multilevel monitoring devices in a single hole at each site. The use of piezometers in numerous boreholes at each monitoring site is often prohibitively expensive for detailed monitoring of contaminant plumes.

This paper describes a simple, inexpensive multilevel monitoring device that was developed for use in fractured rock. The device provides for the measurement of hydraulic head and the collection of water samples from numerous depth levels in a single hole. After two proto-types were constructed in the laboratory, a full-scale assembly was installed in a borehole in fractured limestone at the Upper Ottawa Street landfill in the City of Hamilton, Ontario. This installation served for demonstration of the feasibility of convenient assembly of the device in the field and for a preliminary evaluation of the performance of the device. The results obtained to date are sufficiently en-

couraging that we anticipate using the device as the primary means of groundwater monitoring at the landfill site, if it is descided that detailed monitoring of groundwater at the site should take place.

DESCRIPTION OF THE DEVICE

The device consists of a bundle of tubes contained with a pipe (casing) that is capped on the bottom. Each of the tubes is connected to a 90° elbow, which protrudes through the casing (Figure 1). Each tube extends to a different depth in the casing so that water can be drawn from different depths in the borehole. The interval of boreholes associated with each tube is isolated from the intervals above and below by packers that expand so that the annulus between the casing and the wall of the borehole is sealed over specified intervals (Figure 2.)

The number of tubes that can be installed in a single borehole depends on the diamater of the borehole and on the diameter of the tubes. The borehole used in the experimental field installation had a diameter of 7.5 cm. The PVC pipe used in the installation had an outside diameter of 6.0 cm and a 0.3 cm wall thickness. A total of six 0.3 cm O.D. polyethylene tubes were used in this assembly. One or two additional tubes could have been used, but would have caused considerable difficulty in assembling the device in the field because of the tightness of fit.

In order that the device will be suitable for investigations of hazardous organic chemicals in groundwater, the use of glues was avoided in the assembling of nearly all parts of the device. The 90° elbow (polyethylene) has a 1/8 inch pipe thread on one end which protrudes through a 13/32 inch hole drilled in the PVC pipe. A small O-ring (1/16 x 1/4 x 3/8 in.) was placed on the thread

to prevent leakage of water around the elbow and the PVC pipe. A threaded piece of nylon was screwed onto each of the 90° elbows to hold each elbow tightly in place against the PVC casing.

Other materials could be used for the various components of the device if one desires to avoid some of the plastics because of concerns regarding their influence on the trace-organics composition of the water samples. For example, in some situations stainless steel or aluminum pipe could be used instead of the PVC pipe. Teflon-lined polyethylene or polypropylene tubing could be used rather than the normal tubing. If a larger diameter borehole is used, a larger casing would permit more tubes to be included in the assembly. A 10 cm diameter hole would allow approximately 12 tubes (0.3 cm O.D. tubes) to be fitted into the assembly.

The packers were formed of a gel-like sealant that expands when contacted by water. The sealant, which resembles a soft light rubber, is formed in a cylindrical shape in moulds. It is placed around pre-cut lengths of PVC pipe, the same pipe that is used for the casing so that the packers can be conveniently joined by couplings into the casing. The sealant sections used in the device that was installed at the field site were 9 cm long. Much longer sections of sealants could be made in the same manner, if desired.

The cylindrical packers must be isolated from the groundwater in the borehole along the outside of the casing because the sealant contains soluble inorganic and organic compounds. The sealant must be contacted by water from inside the casing so that volume expansion will occur. To provide for this water contact, holes were drilled radially around the PVC pipe. Monofilament screen cloth (Nitex†, 210 mesh) was taped around the pipe and over the holes. The sealant cylinder was installed around the PVC pipe, with the screen in place

between the pipe and the cylinder. The purpose of the screen is to facilitate the entry of water from inside the PVC casing into the very thin annulus between the exterior of the pipe and the interior surface of the sealant mass. Because the bottom of the casing is capped and because the tubes are tightly sealed where they protrude through the casing to the borehole, the water for expansion of the sealant must be provided by filling the inside of the casing with foreign water.

The outside of the sealant was covered with a flexible rubber membrane (5 cm diameter) that was held in place above and below the membrane by O-rings (1/8 x 2.0 x 2.25 in.). The O-rings sits in groves that were cut into the PVC pipe. A standard PVC coupling was glued onto each end of the length of pipe containing the packer assembly. For the device with six sampling tubes that was installed at the field site, twelve packers were constructed and were taken to the field in a fully-assembled state.

The sealant used in the construction of the packers was obtained from the Dow Chemical Company. It is known as Dowell sealant. The cylindrical mass of sealant was formed by mixing three chemical components together and pouring this mixed liquid into a brass mold. The first component is a powder consisting of polyacrylamide (a polymer), the second is a clear liquid (glycerine) and the third is a liquid contalyst (sodium dichromate). The rubber-like cylindrical gasket is removed from the mold after an overnight set-up period. When the sealant is contacted by water from inside the casing in the borehole, it expands approximately 70% of its volume.

The size of the cylindrical mass of sealant was such that its outside diameter prior to expansion was slightly smaller than the outside diameter of the coupling on each end of the length of PVC pipe used for the packer assembly.

This arrangement provided protection of the sealant when the complete monitoring device was lowered down the borehole. The couplings would scrap on the wall of the borehole rather than the thin, less durable, rubber membrane that covers the sealant.

ASSEMBLY AND INSTALLATION

The packers and fittings for the 90° elbows were constructed in the laboratory but were assembled in the field. It is desirable to assemble the monitoring device in the field so that information obtained while drilling and coring the borehole can be utilized when choosing the spacing of the sampling intervals and packers. Inspection of cores and borehole injection tests can be used to determine the depth levels at which the most important open fractures occur. These levels can serve as the sampling zones and the packers can be placed in positions to seal each zone from the zones above and below. At the field installation site, the spacing of sampling tubes and packers was based solely on the results of visual inspection of cores.

Once the depth intervals for the sampling ports were specified, each sampling port was constructed by drilling a hole in a length of PVC pipe so that the 90° elbows and tubing could be attached to form the sampling ports. A packer was attached by means of glued couplings above and below the length of pipe containing the sampling ports. Lengths of PVC pipe were coupled into the assembly to provide spacing between the sampling intervals.

The borehole at the field site was 19.5m deep. The entire monitoring device was assembled in 6.5 m sections. After each 6.5 m section was put together, a rope was passed through each section in order to assist with the stringing of the sampling tubes when the assemblies were installed in the bore-

hole. The first 6.5 m section was inserted in the borehole to a depth at which only the upper metre protruded from the hole. The bundle of sampling tubes from this section was then drawn by the rope through the next section of PVC pipe. The two sections were coupled together and then lowered into the hole. The procedure was repeated for the third section. The entire assembly was then lowered to the bottom of the hole. The PVC casing was then filled with water so that the packers would expand to provide seals between the sampling intervals.

Although the field installation used a borehole that was only 19 m deep, we expect that the procedures used at this site would be suitable for placing devices in much deeper holes. For the installation procedure to be successful, however, it is necessary that the borehole remain open with no protrusions of rock rubble or overburden into the hole.

MONITORING AND SAMPLING

The measurement of water levels in each of the sampling tubes is accomplished using a narrow-diameter electric probe. Suitable probes are available from commercial suppliers or they can be easily constructed using co-axial cable, a battery and a small volt meter. If the sampling port is properly isolated from zones above and below, the measured water level represents the hydraulic head of the water in the zone of fractures adjacent to the sampling port. A measurement of the hydraulic conductivity of the packer-isolated interval can be performed by falling head or rising head tests in the conventional manner described by Hvorslev (1951) for standpipe piezometers. If the rate of water-level rise or fall is excessively rapid, the sampling tubes can be extended farther above ground level so that rapid changes in water level can be

observed more conveniently.

Water samples can be collected from each of the tubes by pumping. If the depth to water is less than about 7 m, a hand-operated vacuum pump or battery operated paristaltic pump connected to a vacuum flask provides a convenient means of obtaining samples. If the depth to water is greater than about 7 m, a narrow-diameter gas-drive pump such as those that have been recently developed at the University of Waterloo (Robin et al., 1982) can be used. These pumps can be used in tubes as small as 0.3 cm. They displace the water from the tubes by means of positive pressure and therefore there is a minimal opportunity for the chemical composition of the water to change because of loss of dissolved gas such as CO_2 or because of uptake of oxygen. The loss of volatile organic compounds during sampling with these pumps has not yet been evaluated.

PERFORMANCE OF THE DEVICE

After the device was installed at the field site, several weeks were allowed to pass before the device was used for water-level monitoring and sampling. It was expected that this period would allow for the effects of disturbance of the hydrochemical system in the fracture zones caused by drilling to be diminished or obliterated by the natural flow of groundwater. Before and after groundwater sampling, the depth to water were measured. The water level in the deepest tube was above ground surface. The levels in the other tubes were all different and in the range of 1.435 m to 2.375 m below the top of the casing, which was 1 m above ground level. The fact that the water levels were reproducible before and after pumping and that each tube had a different level is supportive of the conclusion that the Dowell seals in the packers expanded

sufficiently to isolate hydraulically each sampling port from the ones above and below.

This conclusion was evaluated further by response tests. As water was pumped from a single tube, the water level in the tube above the tube being pumped was monitored. In each case there was no observed effect of pumping on these water levels, which is what is expected in a situation where the fractures are primarily horizontal and where the packer seals are effective. One of the sampling ports (the third one up from the bottom) was shown to have a crack somewhere in the connectors or coupling caused during installation. When the tube for this port was pumped, an immediate decline in water level in the interior of the PVC casing was observed.

The second stage in the evaluation of the performance of the device involved the acquisition of water samples from the tubes and analysis of the samples for electrical conductance and concentrations of total dissolved organic carbon (DOC) and chloride (total concentrations in samples passed through 0.45 micron filter paper). Each of the six sampling tubes provided groundwater with considerably different values for these three parameters. For example, the Cl^- concentrations ranged from 67,000 mg/L in the deepest tube to 1,600 mg/L in the tube second from the top. The DOC values ranged from a minimum of 13 mg/L (expressed as C) in the fourth tube down from the top to a maximum of 4,200 mg/L in the next tube upward.

From the water level and chemical results there is no significant doubt that each sampling port draws water from a discreet zone of fractures within the borehole and that each of these zones is sampled in isolation from any influence from zones above and below. We conclude, therefore, that the multilevel monitoring device is performing at the field site in the manner that

is desired of it.

CONCLUSIONS

It is our opinion that we have obtained a sufficient amount of information to conclude that the multilevel sampling device that we have developed and tested at the Upper Ottawa Street landfill will serve as a cost-effective means of monitoring the chemical composition of groundwater in the bedrock at this site. For this monitoring to occur in a comprehensive manner, a detailed network of multilevel monitoring devices would need to be installed at the site. We expect that some minor improvements in the design of the device could easily be made prior to the development of a monitoring network.

The preliminary chemical data that have been obtained from the single multilevel device that we installed at the Upper Ottawa Street landfill site indicates that a zone of contaminated groundwater exists in the bedrock. The concentrations of chloride and dissolved organic carbon that were observed in most of the sampling tubes were much higher than the concentrations that are commonly observed in zones of contaminated groundwater at other landfills in Ontario.

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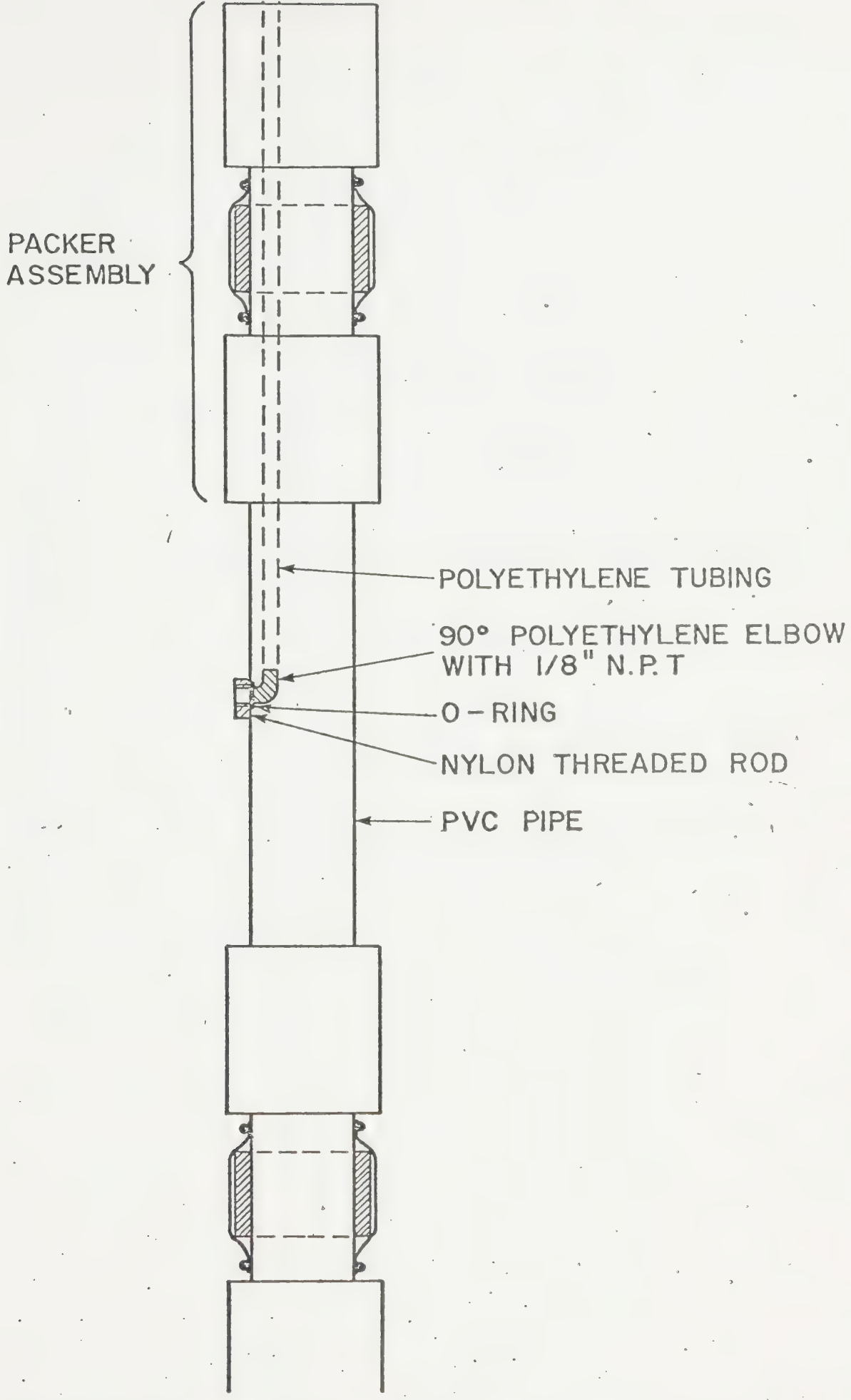

Figure 1. The multilevel monitoring device: a sampling port between two packer assemblies

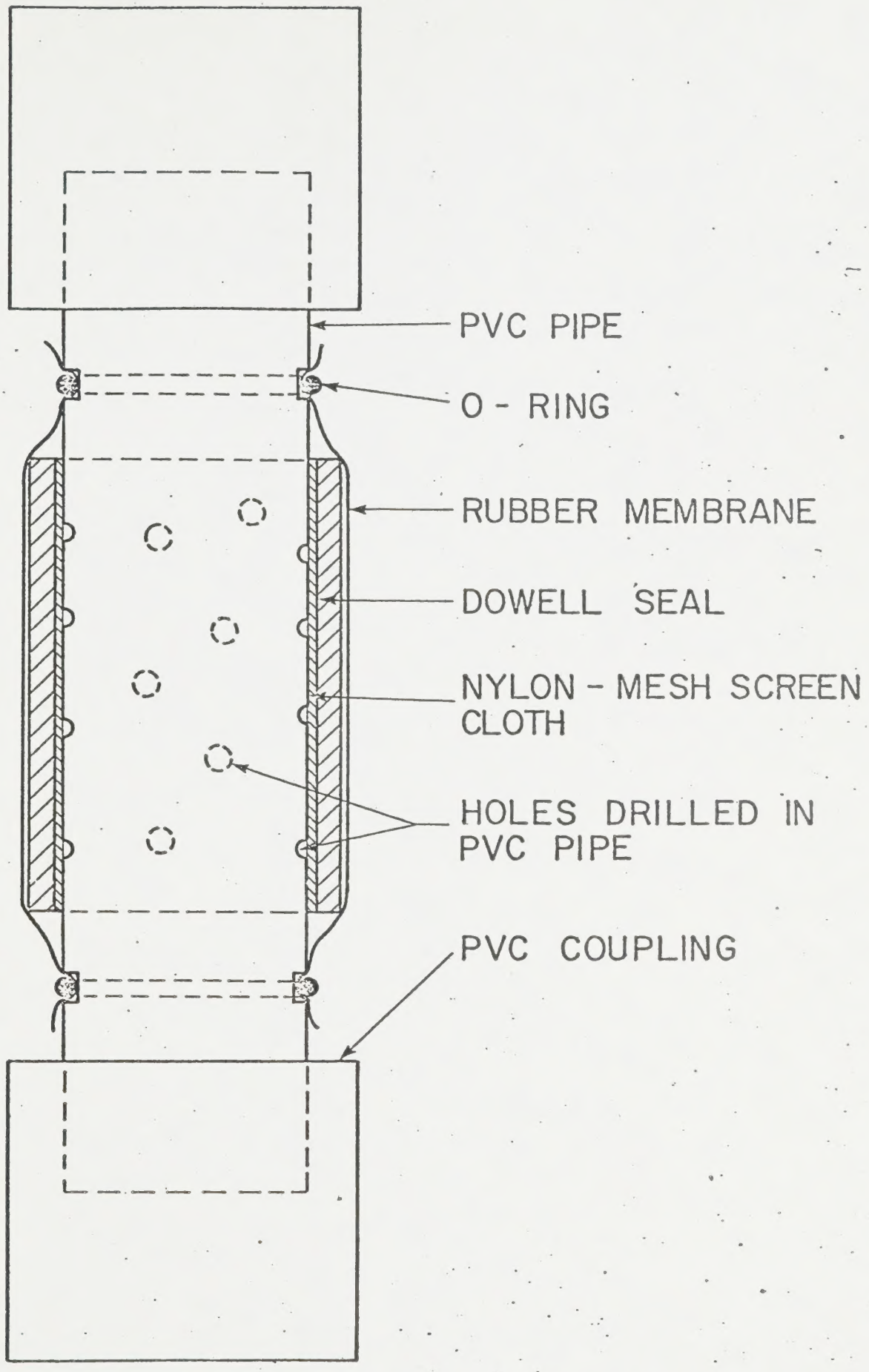

Figure 2. The packer assembly

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